EBONE

European Biodiversity Observation Network:

Design of a plan for an integrated biodiversity observing system in space and time

D1.2: Criteria necessary for determining the improvements from inter-calibration

Version 6.2
Document date: 2010-06-21
Document Ref.: EBONE-D1-2

Authors:

Halada, Ľ., Parr, T., Jongman, R.H.G., Estreguil, C.

Reviewer:

Nilsson, M.

EC-FPV Contract Ref: ENV-CT-2008-212322

Content

1. Executive Summary

The objective of this report is to propose criteria and identify techniques for measuring the improvements made in EBONE project by the inter-calibration process. The term „inter-calibration“ is used in EBONE for linking Earth Observation data with in-situ habitat information: habitat composition in representative test sites, structural characteristics of vegetation and landscape (Fuller et al 2005). The report is focused to three crucial indicators that were identified in the deliverable D1.1 “List of indicators” and will be used in EBONE.

1. Habitats of European interest in the context of a broad habitat assessment;
2. Abundance and distribution of selected species (birds, butterflies and plants); and
3. Fragmentation of natural and semi-natural areas.

The report characterizes for each indicator the current situation of its use and data collection, provides information about expected improvement in EBONE and proposes how to measure the improvement. We tried to select and propose simple measures that can be easily calculated to measure the improvements in monitoring capability done/expected by inter-calibration.

For **habitats** the main improvements are expected in thematic resolution, thematic accuracy, cost-efficiency and refinement of distribution data. The following indices were proposed for measurement of improvements by inter-calibration:

- thematic resolution improvement: new classes index; hierarchical habitat index
- thematic accuracy improvement: producer accuracy, user accuracy, total accuracy (measured by the error /confusion/ matrix and kappa index)
- refinement of distribution data: index of newly detected sites, newly detected habitat area, number of improved grid cells
- cost-efficiency improvement: time effectiveness improvement and cost effectiveness improvement

For **species** is the potential improvement more complicated that for habitats. Because the earth observation techniques seldom allow direct detection of species distribution, it is expected that in EBONE, especially the modeling approach will be used. From the same reason, we do not expect direct modeling of species distribution; species distribution will be rather modeled indirectly by application of the habitat suitability models. As a result of inter-calibration, we expect the improvement of distribution modelling and refinement of distribution data. For measurement of improvements by inter-calibration, we proposed following measures:

- distribution modelling improvement: explanatory and predictive power of the model
- refinement of distribution data: index of newly detected sites, newly detected species distribution area, number of improved grid cells
- cost-efficiency improvement: time effectiveness improvement and cost effectiveness improvement

The pattern, **fragmentation and connectivity** of target land cover and habitat classes are studied in EBONE using three main methods: Morphological Spatial Pattern Analysis, Landscape mosaic index and Connectivity Index. The main limitation is clearly the lack of availability of multiscale and multi-temporal input data, especially habitats maps over large regions, to implement the methods and compare results accross scales. However, we expect progress in methods development related to spatial pattern characterisation and automatic assessment, and connectivity measurement. For the first time the pattern of habitat samples in different countries will be assessed in a harmonized manner and automatically. For

measurement of improvement done by inter-calibration of EO and field in-situ data, we proposed following measures:

- Thematic resolution improvement: application of the methods will be done at habitat level on the basis of the EBONE harmonized habitat samples database and also at land cover level. This would include confusion matrices between habitats and land cover layers. Pattern assessment will be compared across thematic and spatial resolutions.
- Improvement of spatial pattern characterisation methods with emphasis on core/interior and edge/interface aspects of focal habitats including permeability
- Improvement of connectivity measurement: connectivity indices without and with matrix will be developed and applied at habitat and at land cover levels. Models of matrix permeability depending on species habitat preferences and their average dispersal distance will be developed for a more functional connectivity index.
- Cost-efficiency and time effectiveness improvement: Methods are automatic and easily applicable over large regions

The proposed indices can provide quite comprehensive assessment of improvements by inter-calibration in the project EBONE. Some proposed indices were formulated quite generally because the methods related to them that will be applied in EBONE are not yet fully elaborated. This is especially the case in indices proposed for the cost- effectiveness measurement. Currently the efficiency measurement in EBONE is under development, better known are methods for recording and measuring of costs. Thus, some proposed methods will be adapted depending on methods and results of the project. This is permanently being monitored.

2. The introduction and background

Task formulation

Objective 1.4 To develop criteria and techniques for assessing whether there is added value from integrated techniques in order to provide improved estimates of indicators in space and time.

Task 1.4. (Alterra, ILE-SAS) Once the indicators have been identified, criteria will be proposed and techniques identified for measuring the improvements made by the inter-calibration process. The potential for extrapolation will also be examined.

Deliverable D1.2: Criteria necessary for determining the improvements from inter-calibration (M14)

In the EBONE project a system for monitoring of biodiversity is to be developed. This system should be based on existing monitoring methods and specific focus is paid to integration of in-situ and remote sensing methods of biodiversity monitoring (further “monitoring”). Some additional techniques that could improve the quality of monitoring should be used as well, e.g. modelling techniques.
This report will propose how to assess monitoring improvements using inter-calibration of different monitoring techniques. It is focused to three crucial indicators identified in the deliverable 1.1 “List of indicators”

1. Habitats of European interest in the context of a broad habitat assessment;
2. Abundance and distribution of selected species (birds, butterflies and plants); and
3. Fragmentation of natural and semi-natural areas.

These 3 indicators are included in the set of core indicators of biodiversity – SEBI 2011. This report is not dealing with additional 2 indicators that were proposed as potentially useful in D1.1, namely climate change and ecosystem services.

In the work package 4 (Protocols for harmonisation of in situ data) of EBONE, a methodology for in-situ monitoring has been developed (See Deliverable 4.1). The crucial feature of this methodology is use of the General Habitat Categories (GHC) that are based on the proportion of plant life-form types in the habitat. In WP6 (Validation in test sites) and WP9 (Validation of the methodology outside Europe) the methodology will be tested in the field and field data will be produced for test areas of size 1 km^2. The inter-calibration of EO data and field data is crucial theme of WP5 (Inter-calibration of EO data with in situ data). This WP should use in situ data and other ancillary data for enhancing monitoring abilities of remote sensing In WP8 (Institutional arrangements and cost effectiveness), the system for monitoring should be developed and its cost-effectiveness assessed.

In this report we tried to select and propose simple measures that can be easily calculated to measure the improvements in monitoring capability that could be gained by adopting these new approaches.

3. Habitats

3.1 Current situation

On a Pan-European scale two habitat classifications have been developed: Palaearctic habitat classification (PHYSIS, Devillers et Devillers 1996) and EUNIS habitats (e.g. Davies et Moss 2002). Both classifications are hierarchical and cover the full spectrum of habitats occurring in Europe and are related in their systematics. Both classifications are meant to be suitable for field mapping. For EUNIS habitats, no consistent database for field mapping exists. The PHYSIS classification was used as background for CORINE Biotopes that was used by several countries for development of Emerald network under Bern convention. Their application at regional level is feasible, but application at the European level is problematic due to its character as a compilation of expert systems from different parts of Europe, which caused insufficient unambiguity in definitions of habitat classes, their environmental conditions and the use of biogeographical terms.

Based on EUNIS, a classification of habitats is used by the Habitats and Species Directive in which habitat types are listed as Annex I habitats. This list contains only selected habitat types that are organized on 2 levels: the first level corresponds to broad habitat types, the second level contains in one level habitats that are classified by PHYSIS and EUNIS habitats in different hierarchical levels. Annex I habitats are used especially for prioritising nature conservation actions and for reporting in this field. Recent distribution maps of Annex I habitats exist, covering all countries of European Union. The member states delivered them to EC within the framework of the Habitat Directive Article 17 reporting in 2007. The quality (nature and resolution) of these datasets greatly varies among countries – it ranges from very precise polygon data to coarse grid distribution. Therefore they were converted by ETC BD to a uniform grid that can be used in European level (http://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec). However, also this database expresses the differences between countries and does not show lacking data.

Besides habitat classifications, also relevant to this report are phyto-sociological classifications used for vegetation research. Vast amounts of vegetation records exist across Europe describing vegetation in small plots (up to several hundreds m^2), they are stored both in national databases and in databases of individual institutions or scientists. The most commonly used database is SynBioSys, that covers vegetation data from many European countries. SynBioSys Europe, an initiative of the European Vegetation Survey, is an information system for the evaluation and management of biodiversity among plant species, vegetation types and landscapes. (http://www.synbiosys.alterra.nl/). It is possible to translate vegetation records into habitat classifications (EUNIS, PHYSIS, Annex I) and also to translate individual units between habitat classifications However, the crosswalks between phytosociological units and EUNIS does not always provide clear relationships (Rodwell et al 2002).

In addition to Pan-European, national classifications exist in different countries of Europe and they are used in different degree for field research or mapping.

Earth observation can also produce data about habitats. On Pan-European scale, the standard product is produced in programme CORINE Land Cover (CLC). Land Cover, however is not the same as habitats. CLC is a hierarchical system and the standard product at CLC level 3 contains 44 classes. The CLC maps are available for years 1990, 2000, and 2006. Its advantage is whole coverage of European Union, standard methodology and availability of 3 time horizons. There are limitations both in thematic resolution (44 classes corresponding to broad habitat types) and in spatial resolution (corresponding to scale

1:100.000; spatial parameters for minimal polygon size and minimal size of change). Because patches of many habitat types could have (or typically have) patch size smaller than minimal parameters of CLC, their occurrence is usually not registered or registered only partially. The thematic resolution is especially restricted in smaller habitats and complex systems that are not included. Also deciduous and non-deciduous broadleaved forests have not been separated from each other.

There exist some national mapping programs that can provide information about habitats, NILS (Sweden), Countryside Survey GB), the Northern Ireland Countryside Survey (NICS) and SISPARES (Spain) are best known. They combine earth observation approach and field mapping.

The S**wedish national landscape biodiversity** monitoring program NILS (National Inventory of Landscapes in Sweden) is developed to monitor conditions and changes in landscape biodiversity and land use as basic input to national and international environmental frameworks and reporting schemes and to applied research. NILS has been in operation since 2003 with two parallel and integrated inventory routes, field inventory and interpretation of colour infrared aerial photos, both using quantitative variables in a context-dependent flow that captures spatial information on species, habitats, structures and processes. The design is a stratified grid of 631 permanent large-size (5 km x 5 km) squares covering all terrestrial habitats in Sweden, from alpine mountains to urbanized areas.

Countryside Survey is a unique study of the natural resources of the GB countryside (GB-CS) involving a detailed field survey of habitats, vegetation, freshwater and soils across England, Scotland and Wales. A separate study of habitats is undertaken in Northern Ireland (NICS). The Survey is undertaken every 6-8 years and normally reports at the country and GB level, but it has grown in complexity. Individual survey squares of 1 km squares were stratified randomly selected so that they represent variations in climate and geology across the country. In Northern Ireland the survey squares measure 0.25 km^2. Widespread terrestrial habitat types are sufficiently well represented to enable robust and reliable statistical analyses. The locations of the survey squares are not disclosed to avoid any deliberate influences that could affect them or the features within them. In this way, the survey squares will remain representative of changes in the wider countryside and will continue to provide a reliable comparison for future surveys. Areas of habitat were mapped within each square and more detailed samples were made of vegetation in a series of plots.

SISPARES is the Spanish national landscape-monitoring scheme for monitoring of rural landscapes. It is based on a combination of aerial photography-based interpretation of land cover and field mapping surveys in 206 samples of 4x4 km squares. The methodological approach is designed to understand and characterize the structure of landscapes, and to analyze their dynamics over time.

On the Pan-European level, CORINE Land Cover and Annex I habitat maps can be used as background for assessment of EBONE improvement by inter-calibration process, on national level, all 3 programmes mentioned above (UK countryside survey, NILS, SISPARES) can be used.

3.2. Expected improvement in EBONE

The link between earth observation and habitats provides the focus for inter-calibration work in EBONE. In the deliverable D1.1, the first selected indicator is on “Habitats of European interest in the context of a broad habitat assessment”. This name expresses the fact that in the European biodiversity policy and in SEBI 2010 indicators, the main attention is paid to so called “habitats of European importance” – i.e. habitat types listed in Annex I of the Habitat Directive. However, Annex I contains habitats of different hierarchical level: some of them represent quite broad habitat types, clearly distinct from other habitat types while some others are defined in much narrower way and the differences against other types are not so evident. Moreover, there exist high number of habitats that are not included into Annex I, some of them are quite similar to Annex I habitat types. Therefore ability of inter-calibration to distinguish directly Annex I habitat types will be limited, we expect the main contribution of EBONE to be related to the identification of broader habitat types. Therefore the main part of this chapter deals with habitats generally, where appropriate, improvement of Annex I habitats detection is discussed as well.

The following types of monitoring improvement by inter-calibration in EBONE are expected:

- Thematic resolution improvement
- Thematic accuracy improvement
- Refinement of distribution data
- Improved statistical estimates of indicators or habitats
- Cost-efficiency improved

For the expected EBONE product we will be able to specify accuracy and reliability for each habitat type separately, which is not case of other current products.

3.3. Measuring of improvement

Thematic resolution improvement

Different remote sensing products currently distinguish different number of land cover classes. The land cover classes could be interpreted as habitat types of certain hierarchical level (usually higher level, with coarse resolution). As it was mentioned above, e.g. CORINE Land Cover level 3 distinguishes 44 classes.
It is expected that EBONE product will have increased thematic resolution, it will be able to detect more classes. Two indicators are proposed for thematic resolution: new classes index (NC) and the hierarchical habitat index (HI).

<u>The new classes index</u> (NC) is simple measure expressing the ratio of number of newly distinguished habitat types to all distinguished habitat types:

$$NC = U_N/N \; ; \qquad (1)$$

where $U_{N\ is}$ number of newly distinguished habitat types and N is number of all distinguished habitat types.

<u>Hierarchical habitat index</u> (HI) is a measure expressing the degree of thematic resolution. It compares mapping/monitoring products to the reference hierarchical classification of habitats. In the first step, for each class distinguished by the EBONE product and other compared product (e.g. CLC) the corresponding hierarchical level in the reference habitat classification is determined. Then the HI is computed:

$$HI = \frac{1}{N}\sum_{i=1}^{N} HL_i \qquad (2)$$

where HL_i is hierarchical level of class i and N is number of classes. Consequently, the inter-calibration improvement iHI is computed as:

$$iHI = (\Sigma\ HLE_{1\text{-}N}/N_E) - (\Sigma\ HLO_{1\text{-}N}/N_O) \qquad (3)$$

where HLE is hierarchical level of habitat type distinguished by new EBONE product, HLO is hierarchical level of habitat type distinguished by other, compared product, N_E and N_O is number of distinguished classes (habitat types) by the respective products.

The classification used for intercalibration should be used as a reference classification, alternatively the maps with and without intercalibration can be compared with suitable standard classification (e.g. EUNIS habitats. Because the field mapping in EBONE is based on General Habitat Categories, this classification can be used as the reference classification as well, taking life forms as a highest hierarchical level.

Thematic accuracy improvement

The final product of classification will be compared to the reference data (field based data, another existing product – e.g. CORINE Land Cover.) and degree of correspondence between these two datasets will be assessed as follows:

- **Producer’s accuracy** (commission error) - how often does the map correctly predict known features.
- **User’s accuracy** (omission error) - how often will the map successfully lead the user to unknown features.
- **Total accuracy** (overall accuracy) - combination of producer’s and user’s accuracies.

For the calculation of accuracy, the sampling design should be representative for purposes of accuracy assessment (should adequately represent the distribution of the desired classification products – locations of both presence and absence). Because of this requirement, the suitable reference dataset usually does not exist before the classification is done and it is necessary to produce it within the project. Therefore the accuracy assessment is usually very expensive, sometimes up to 1/3 of total project cost.

Because in EBONE the accuracy assessment will be done for inter-calibrated product, the data used for inter-calibration cannot be used for assessment of accuracy, for this purpose the additional independent dataset is necessary. CORINE Land Cover and Annex I distribution maps mentioned above can be used on European level, different habitat and land cover maps can be potentially used on regional and local levels.

For use in EBONE, we propose 2 measures: confusion matrix and kappa index.

The calculation of the Error (Confusion) Matrix is explained in the table and equations below.

		Reference (Field) Data			Totals
		Class 1	Class 2	Class 3	
Classified Data	Class 1	C_{11}	F_{12}	F_{13}	T_{1x}
	Class 2	F_{21}	C_{22}	F_{23}	T_{2x}
	Class 3	F_{31}	F_{32}	C_{33}	T_{3x}
	Totals	T_{x1}	T_{x2}	T_{x3}	N

where C_{ij} is number of samples identically classified both by classified data and reference data (correctly classified); F_{ij} is number of samples differently classified by classified and reference data (false classified), T_{ij} are the respective totals, N is number of samples. Then individual accuracies are calculated for individual classes as:

Producer's Accuracy: $P_{xj} = C_{xj/} T_{xj}$

User's Accuracy: $P_{ix} = C_{ix/} T_{ix}$

Overall Accuracy: $P = \Sigma C_{ij}/N$

The producer and user´s accuracy can be calculated separately for each class or for all classes

Many measures of classification accuracy may be derived from a confusion matrix. The Kappa coefficient can be generated to describe the proportion of agreement between the classification result and the validation sites after random agreements by chance are removed from consideration these data (Thomas et. al., 2002). In thematic mapping from remotely sensed data, the term accuracy is used typically to express the degree of 'correctness' of a map or classification (Foody, 2002).

There are different types of Kappa index, it can be calculated as follows:

$$\kappa = \frac{P_c - \sum_{k=1}^{q} p_{k+} p_{+k}}{1 - \sum_{k=1}^{q} p_{k+} p_{+k}},$$

$$\text{where } p_{k+} = \sum_{j=1}^{q} p_{kj}, \text{ and } p_{+k} = \sum_{i=1}^{q} p_{ik}.$$

where P_c - overall proportion of area correctly classified, p_{ij} - individual cell probabilities; p_{i+} and p_{+j} - row and column marginal proportions, respectively (Stehman 1997).

The improvement achieved by inter-calibration will be calculated as the difference between classification without inter-calibration and with inter-calibration.

Refinement of distribution data

Habitat distribution data vary considerable throughout Europe. The CORINE Land Cover (CLC) is probably the only product that is standardized and displays distribution across Europe of land cover classes that can be translated to (broad) ecosystem/habitat types. Therefore the CLC will serve as the main reference dataset for assessment of monitoring improvement by inter-calibration (despite its limitations addressed above). The distribution maps delivered for Annex I habitat types for the Habitat Directive Article 17 assessment in 2007 represent another potential reference dataset on European level, although it is rather unbalanced in its underlying data. On national level, besides the above mentioned programmes (NILS, GB CS, NICS, SISPARES) datasets produced by different national inventory, mapping and monitoring programmes could be used as the reference dataset.

The inter-calibration improvement should result in the ability to detect more precisely habitat types and to refine maps of habitat distribution. For the refinement of distribution data we propose 3 measures: number of new sites detected, area of new sites and number of grid cells with more precise habitat mapping. . These should be calculated in relation to a certain reference area.

<u>Index of newly detected sites (Sh).</u> A "site" is considered as a polygon of assessed habitat type bordering with polygons of other habitat types in the respective dataset. Calculation:

$$Sh = n/N;$$

where n is number of newly detected polygons by inter-calibration and N is number of all polygons in the product. Alternatively, number of polygons in the product developed with inter-calibration can be compared to the number of polygons in the product developed without inter-calibration.

Newly detected habitat area (Ah). This expresses the ratio of area of newly detected polygons and area of all polygons (can be calculated for certain habitat type or for all habitat types). Calculation:

$$Ah = A_N / A_T ;$$

where A_N is area of polygons newly detected by inter-calibration and A_T is area of all polygons in the product.

Number of improved grid cells (Gh). This measure can be used especially if the reference dataset expresses the habitat presence using a grid network. In this case, usually the habitat type is present only in part of the area covered by the respective grid cell and the product developed in EBONE can specify distribution inside of the grid cell more precisely (divide the cell into area in which the habitat type is present and area in which is not distributed). In such case we can express improvement produced by inter-calibration in number of cells where habitat distribution was improved/refined. Calculation:

$$Gh = G_N/ G_T;$$

where G_N is number of grid cells with habitat distribution refined by inter-calibration and G_T is number of all grid cells in the product. Alternatively, the number of grid cells with a refined habitat distribution in the product developed with inter-calibration can be compared to number of grid cells refined in the product developed without inter-calibration.

Cost-efficiency improvement

By definition, the cost-effectiveness analysis (CEA) is a form of economic analysis that compares the relative costs and outcomes (effects) of two or more courses of action. Cost-effectiveness analysis is distinct from cost-benefit analysis which assigns a monetary value to the measure of effect. The purpose of cost-effectiveness analysis is to ascertain, which alternative method or their combination can achieve particular objectives at the lowest cost. The underlying assumption is that different alternatives are associated with different costs and different results. By choosing those with the least cost for a given outcome, society can use its resources more effectively (Levin 2005).

Before starting the cost analysis, it is necessary to know what the decision problem is, how to measure effectiveness, which alternatives are being considered and what their effects are. Once the problem has been formulated, it will be necessary to consider how to assess the effectiveness of alternatives. For this purpose, clear dimensions and measures of effectiveness will be needed. Given the problem and criteria for assessing the effectiveness of proposed solutions, it is necessary to formulate alternative programs or interventions. It is important to emphasize that the evaluation of effectiveness is separable from the evaluation of costs. Most standard evaluation designs for assessing the effectiveness of an intervention are also suitable for incorporation into cost-effectiveness studies.

The most common measure of cost-effectiveness is the cost-effectiveness ratio, namely, the effectiveness of an alternative divided by its cost. When this is done for each alternative, it is possible to see which of the alternatives yields the best outcomes per unit of cost.

In this measure, the cost for development of efficiency with inter-calibration can be compared to cost efficiency without inter-calibration. In EBONE time will be registered that is spent for mapping and this can be used for costs calculation. However, currently it is not clear, how the effectiveness will be defined in EBONE. Therefore the way of cost-efficiency improvement by inter-calibration could be formulated only in general terms currently.

We propose to measure cost-efficiency improvement by comparing cost effectiveness reached by inter-calibration with the cost effectiveness without inter-calibration. Two measures are proposed: time effectiveness improvement and cost effectiveness improvement.

Time effectiveness improvement (TEI) is measured as ratio of time effectiveness with inter-calibration and time effectiveness without inter-calibration:

$$TEI = TE_I / TE_W ;$$

where TEI is time effectiveness improvement; TE_I is time efficiency with inter-calibration and TE_W is time efficiency without inter-calibration.

Cost effectiveness improvement (CEI) is measured as ratio of cost effectiveness with inter-calibration and cost effectiveness without inter-calibration:

$$CEI = CE_I / CE_W ;$$

where CEI is cost effectiveness improvement; CE_I is cost efficiency with inter-calibration and CE_W is cost efficiency without inter-calibration.

4. Species

4.1 Current situation

Species' mapping and monitoring has a long tradition in Europe. Numerous datasets exist at national level for different species group and also several European datasets.

For plants, the taxonomical project Flora Europaea (results published in 5 volumes between 1963 and 1994) was followed in 1965 by launching of long-term project for mapping the distribution of vascular plants in Europe – "Atlas Florae Europaeae". In 1972–2007 fourteen volumes of the Atlas were published with 3912 maps covering over 20% of the vascular plants of Europe (see http://www.fmnh.helsinki.fi/english/botany/afe/index.htm). Despite its limitation (coarse resolution - grid map with squares of ca 50 km x 50 km and coverage only part of European flora), this dataset represents the most important source of plant distribution data at a European level.

Distribution data on animals on a European scale are available especially for most vertebrates and for most popular groups of invertebrates like butterflies and dragonflies. Birds represent the best studied group of animals. The EBCC Atlas of European Breeding Birds (Hagemeier et Blair 1997) represent important datasets, the on-line distribution maps are available on http://www.sovon.nl/ebcc/eoa/. In 2002, the European Common Bird Monitoring Scheme has commenced with goal to use common birds as indicators of the general state of nature using scientific data on changes in breeding populations across Europe. The results of monitoring are regularly published, the last report is PECBMS (2009).

The atlases of distribution in Europe were published also for amphibians and reptiles (Gasc et al. 1997) and mammals (Mitchell-Jones et al., 1999). The distribution of fish is published in the series of books "The Freshwater Fishes in Europe" (8 volumes published so far). The most common database on fish, without distribution data is FishBase, a comprehensive database of information about fish. It includes descriptions of over 31,000 species and references to more than 42,000 works in the scientific literature (see http://www.fishbase.org).

The distribution data on the European level exist for some invertebrate groups only. They are available e.g. for butterflies (Kudrna 2002) and dragonflies (Askew 2004).

For the species of European importance (species listed in Annex II and Annex IV of the Habitat Directive) there exist additional sources of distribution data – the distribution maps delivered to EC by member states in framework of the Habitat Directive Article 17 reporting in 2007. The quality (nature and resolution) of these datasets varies greatly among countries – it ranges from very precise polygon data to coarse grid distribution. Therefore they were converted by ETC BD to uniform grid that can be used in European level.

4.2. Expected improvement in EBONE

Because the earth observation techniques seldom allow direct detection of species distribution, it is expected that in EBONE, especially the modeling approach will be used. Taking into account that the participation of remote sensing in inter-calibration and modeling is planned, we do not expect direct modeling of species distribution. Species distribution will be modeled indirectly by application of the habitat suitability models. The result will be thus not the probability map of species occurrence, the result will be the (map of) habitat suitability for the respective species.

The direct species monitoring can be applied only for those species that are highly dominant in the habitat. They create the main part of the habitat biomass and thus determine the physical parameters of the respective habitat type that are detected by the remote sensing.

Following types of monitoring improvement by inter-calibration in EBONE are expected:

- Improvement of distribution modelling
- Refinement of distribution data

4.3. Measuring of improvement

Improvement of distribution modelling

A vast amount of modelling approaches is available, techniques and models that could be potentially used in EBONE. Therefore also the computation of explanatory and predictive power of these models will be different, depending on model used.

In EBONE, the habitat suitability models will be enhanced by use of parameters developed by the inter-calibration approach. Than the improvement could be measured by comparison of results developed with and without inter-calibration. The result product will be compared also to reference data (e.g. atlas data, results of mapping campaigns or regular field monitoring) using both spatial statistics and distribution statistics. Also indices described in next paragraphs can be used.

Refinement of distribution data

The species' distribution data from different sources (mentioned above) vary considerable throughout Europe and the degree of improvement reached in EBONE will significantly depend on quality of the reference dataset in question. The results of European mapping programmes mentioned above can be used as a reference datasets for measuring the improvement in EBONE.

The distribution maps delivered for Annex II and Annex IV species for the Habitat Directive Article 17 assessment in 2007 represent one of potential reference dataset on a European level. On a national level, datasets produced by different national inventory, mapping and monitoring programmes could be used as the reference dataset.

For the refinement of distribution data we propose 3 measures: number of new sites detected, area of new sites and number of grid cells with refinement distribution. These should be calculated in relation to certain reference area.

Index of newly detected sites (Ss). As "site" is considered as a polygon of assessed species occurrence in the respective dataset. Calculation:

$$Ss = n/N;$$

where n is the number of newly detected polygons by inter-calibration and N is number of all polygons in the product. Alternatively, the number of polygons in the product developed with inter-calibration can be compared to number of polygons in the product developed without inter-calibration.

Newly detected species distribution area (As). Express ratio of area of newly detected polygons and area of all polygons. Calculation:

$$As = A_N / A_T\,;$$

where A_N is area of polygons newly detected by inter-calibration and A_T is area of all polygons in the product. Alternatively, area of species distribution in the product developed with inter-calibration can be compared to the area of species distribution in the product developed without inter-calibration.

Number of improved grid cells (Gs). This measure can be used especially if the reference dataset expresses the species presence using grid network. In this case, usually the species is distributed only in part of the area covered by the respective grid cell and the product developed in EBONE can specify distribution inside of the grid cell more precisely (divide the cell into area in which the species is present and area in which is not distributed). In such case we can express improvement produced by inter-calibration in number of cells where the species distribution was improved/refined. Calculation:

$$Gs = G_N / G_{T;}$$

where G_N is number of grid cells with species distribution refined by inter-calibration and G_T is number of all grid cells in the product. Alternatively, number of grid cells with refined species distribution in the product developed with inter-calibration can be compared to number of grid cells refined in the product developed without inter-calibration.

Cost-efficiency improved

Similarly as for habitats, also for species we propose to measure cost-efficiency improvement by comparing cost effectiveness reached by inter-calibration with the cost effectiveness without inter-calibration. Two measures are proposed: time effectiveness improvement and cost effectiveness improvement.

Time effectiveness improvement (TEI) is measured as ratio of time effectiveness with inter-calibration and time effectiveness without inter-calibration:

$$TEI = TE_I / TE_W ;$$

where TEI is time effectiveness improvement; TE_I is time efficiency with inter-calibration and TE_W is time efficiency without inter-calibration.

Cost effectiveness improvement (CEI) is measured as ratio of cost effectiveness with inter-calibration and cost effectiveness without inter-calibration:

$$CEI = CE_I / CE_W ;$$

where CEI is cost effectiveness improvement; CE_I is cost efficiency with inter-calibration and CE_W is cost efficiency without inter-calibration.

5. Fragmentation (pattern and connectivity)

5.1 Current situation

The SEBI2010 indicator reporting process (particularly indicator 13 the fragmentation and connectivity of ecosystems) and the MCPFE - The Ministerial Conference on the Protection of Forests in Europe (particularly MCPFE-Indicator 4.7: landscape level forest spatial pattern) need large scale (European-wide) assessments for their set of indicators. The lack of harmonized comprehensive (wall to wall) habitat level EU wide map is an obvious limitation to address these two indicators (including monitoring progress): habitats areas and the pattern / fragmentation / connectivity of habitats.

Multi-scale assessments of pattern/spatial connectivity will be implemented in the EBONE project. Each observation scale brings its own picture of fragmentation and connectivity. Data inputs are therefore key for any pattern assessment. Broad habitat maps at Minimum Mapping Unit of 1 ha, would be a minimum (and feasible with current knowledge and technology) requirement to address such issue at European scale and to capture ecologically relevant landscape processes and monitor changes. For the moment land cover serves as a proxy to observe and report landscape processes where habitats are involved (and it is not a one to one correspondence) (Estreguil and Mouton 2009). Regarding reporting units for the landscape processes, relevant spatial units should not be too large to capture local spatial pattern process, that's why it is advisable to report per fixed area grid (10 km^2 or 50 km^2), per provinces or per any other not too large units and then aggregate (or only present) the results for large regions (like countries, biogeographic regions or Environmental Zones).

The approaches that are proposed in EBONE are based on three available methods that have been applied for forest fragmentation analysis over Europe (Estreguil and Mouton, 2009 ; Saura et al, 2010): Morphological Spatial Pattern Analysis (MSPA-GUIDOS freeware, Soille and Vogt, 2009), Landscape mosaic index (adapted from Riitters et al, 2009) and Probability of Connectivity Index (adapted from CONEFOR freeware, Saura and Pascual-Hortal 2007). These methods are currently applied to forests, but they could be used for other classes (land cover classes, habitat types) as well. Within EBONE, due to the lack of temporal habitat series, the pattern assessment will be done at one point in time.

Morphological Spatial Pattern Analysis. Seven types of pattern classes are distinguished for a focal class of interest based on their mathematical morphological characteristics: core, edge, branch, connector-bridge, connector-loop, perforation edge, islet (for definition, see Estreguil and Mouton, 2009. They are automatically and precisely mapped at pixel-level from any raster binary input using freeware GUIDOS (Soille and Vogt, 2009).

The Landscape Mosaic Index characterises the landscape context of a focal class by the proportion of the 3 land cover types (Urban, Agriculture, Natural) in its neighbouring area. Its strength relies in discriminating areas of the focal class in a purely natural landscape context from areas with a more mixed pattern with agriculture or artificial lands (the so called *mitage* effect). Also this index enables the identification of edge interfaces more or less permeable depending on the adjacent land cover types.

Forest connectivity index (partly based on Conefor freeware). Two types of connectivity definition are distinguished - structural and functional connectivity:

1) structural connectivity is degree of habitat connectedness (Merriam 1984) and it is based solely on structural parameters of habitat and landscape matrix
2) functional connectivity depends on habitat availability, dispersal ability of the species and their response to the nature of the matrix. Thus, besides structural parameters it takes

into account also species behaviour and its dispersal ability. This measure requires ecoprofile information.

The measures of connectivity starts with the application of the Probability of forest Connectivity (PC) index applying a neutral matrix and selecting from selected ecoprofiles average dispersal species capabilities. The method is based on topology (inter patch distances) and patch attributes (area) for species with a specific dispersal ability. The index combines landscape graph theory, a probabilistic connection model and the habitat availability concept (Estreguil and Mouton, 2009). The Equivalent Connected Area (ECA), which equals the square root of numerator of the PC index (PC), enables to account for the forest amount (applied over Europe in Saura, Estreguil et al, 2010). It is defined as the size of a single patch (maximally connected) that would provide the same probability of connectivity (PC) than the actual forest landscape pattern. The PC index is further developed to account for the matrix permeability and habitat requirements. Another similar index is also developed in EBONE.

We expect that EBONE will address both structural and functional connectivity.

5.2. Expected improvement in EBONE

The methods that can be run European-wide with the currently available computing capacity are used and further developed in EBONE. However, due to lack of EU wide broad habitats maps, till now it was necessary to focus on land cover and not habitats. Therefore land cover has been used instead of habitat maps so far (Estreguil and Mouton, 2009; Saura, Estreguil et al (final revision 2010). In EBONE we expect the application of the methods on land cover types and on habitat types for pattern and connectivity analysis.

The only way to improve assessment of fragmentation and to link it better to habitats is to get EO based land cover maps calibrated with field-surveys habitat data. The quality of our fragmentation / connectivity assessment depends directly on the quality of the data input. The habitat areas statistics are irrelevant to assess any pattern indicator, the latter require continuous raster or vector layers (wall to wall) habitat (or land cover) maps to run the methods used in EBONE.

EBONE will be the first real case study for applying the same methods over a set of available 1km^2 samples offering land cover and habitat maps. The differences and similarities of the pattern/connectivity assessments made at land cover level from Earth Observation based land cover maps and the ones made from in-situ habitats maps, will bring interesting value-added. Multi-scale thematic information available is for General Habitat Categories and for land cover classes, the former used a minimum mapping units of 400m^2 while the latter used 1ha and 25 ha Both thematic details exist over the EBONE 1km^2 samples database while land cover is available over a regional part of environmental strata. Reporting is envisaged per selected environmental zones in Europe where samples are ready and available. The spatial analysis units are 1 km^2 samples, a fixed area grid (10, 25 km or 50 km grid still to be defined depending on computing capacities) and environmental regions.

We expect progress in methods development related to spatial pattern characterisation and automatic assessment, and connectivity measurement. For the first time the pattern of habitat samples in different countries will be assessed in a harmonized manner and automatically. For measurement of improvement by inter-calibration we proposed following measures:

- Thematic resolution improvement: application of the methods will be done at habitat level on the basis of the EBONE harmonized habitat samples database and also at land cover level. This would include confusion matrices between habitats and land cover layers. Pattern assessment will be compared across thematic and spatial resolutions.

- Improvement of spatial pattern characterisation methods with emphasis on core/interior and edge/interface aspects of focal habitats including permeability.
- Improvement of connectivity measurement: connectivity indices without and with matrix will be developed and applied at habitat and at land cover levels. Models of matrix permeability depending on species habitat preferences and their average dispersal distance will be developed for a more functional connectivity index.
- Cost-efficiency and time effectiveness improvement: Methods are automatic and easily applicable over large regions

The crucial improvement is expected in **thematic resolution**. Till now, most fragmentation exercises were done for land cover types, as a proxy of broad habitat types. The methodology was never applied at habitat level and compared to land cover based results

Inter-calibration in EBONE could provide better input maps with distribution of narrower habitat types. Thus also landscape mosaics will be refined (more types distinguished and therefore also more patches mapped, the average size of patches should decrease). The increase of thematic resolution will shift our measurement of fragmentation closer to the reality and it will allow to assess better the functional connectivity – based on habitat requirements of studied species.

5.3. Measuring of improvement

Fragmentation is a process over time which involves habitat loss and isolation processes. For its study, usually two or more time layers are necessary, which will not be the case in EBONE for habitat layers. We prefer use terms like pattern and connectivity which will be addressed at one point in time for habitats in EBONE, land cover layers in EBONE will enable the study of fragmentation processes which involve the change in pattern and loss of connectivity.

Thematic resolution improvement

The thematic resolution improvement of pattern/connectivity analysis refers to improved thematic resolution of input maps and indexes proposed above in chapter 2.3 can be used: the new classes index and hierarchical habitat index.

Improvement of spatial pattern detection

Measures available from the MSPA-GUIDOS raster products will be for example the share of the seven pattern classes of a focal habitat per analysis unit, or more simply the core habitat area index (CAI) and the edge habitat area index, or the traditional area weighted core average patch size (AWACPS) index. The improvement is measured as difference in indices values of products obtained with and without inter-calibration, or from land cover maps and from habitat maps. The value added in thematic and spatial details could be addressed.

The core area index (CAI) is a simple measure expressing ratio of core area to the total area of habitat/land cover type all 7 distinguished spatial pattern classes:

$$CAI = p_{CA} / \Sigma\, p_i \;;$$

where p_{CA} is core area size and p_i is area of individual spatial patter class (i=1-7).

The area weighted average core patch size index (AWACPS) is based on the identification of core forest patches and accounts for their number and their size. The larger the patch is, the higher its contribution in the calculation. The index formula is:

$$AWACPS = \sqrt{[\Sigma(c_i)^2 / \Sigma c_i]} ,$$

where c_i is area of the core unit i, i=1 to n.

Measures available from the Mosaic index (typically the share of the different landscape pattern types for a focal class per analysis unit, or the permeability of edge interface index) will be applied and the level of details compared at land cover and habitat levels.

Improvement of connectivity measurement

We will use 2 connectivity measures – connectivity indices based on or similar to PC (including the Equivalent Connected Area (ECA)) with and without matrix , the measure for improvement is difference in indices values of products obtained with and without inter-calibration, again from land cover and habitat based maps.

Connectivity index (PC) is calculated as:

$$PC = \sum_{i=1}^{n}\sum_{j=1}^{n} a_i \cdot a_j \cdot p_{ij}^* \quad ;$$

where a_i, a_j = area of patch i,j and p_{ij}^* is product of p_{ij} for all the links in the optimal path between patches i and j. Euclidean distance and least cost path is used for calculation of optimal path (for details see Estreguil and Mouton, 2009; Saura, S., Estreguil, C. et al 2010).

The Equivalent Connected Area index (ECA) is the square root of numerator of the PC index:

$$ECA = \sqrt{PC}$$

Cost-efficiency and time effectiveness improvement:
The timing of pattern and connectivity computing processes will be detailed and special care will be paid on automation of the processing process. It is expected that the pattern spatial database will be further integrated into WP7 spatial infrastructure together with the inputs $1km^2$ samples.

6. Conclusions

In this report, we proposed a quite broad spectrum of indicators for measurement of improvements expected in the EBONE project by inter-calibration approach for 3 main indicators selected for EBONE: **habitats** of European interest in the context of a broad habitat assessment; abundance and distribution of selected **species**; and **fragmentation (pattern/connectivity)** of natural and semi-natural areas.

The report was prepared in time when not all methods that will be applied in the EBONE project, were sufficiently known. Therefore the expected improvement in EBONE was estimated on the basis of available information. Further progress especially in the work packages 4 (Protocols for harmonisation of in situ data), 5 (Inter-calibration of EO data with in situ data), 6 (Validation in test sites) and 8 (Institutional arrangements and cost effectiveness) will allow adaptation of proposed methods and indices for measurement of improvements by inter-calibration.

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